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METHOD AND ITS TRIAL INSTRUMENTATION FOR HIGH SPEED AND CONTINUOUS 3-D MEASUREMENT

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ABSTRACT

This system is based on slit-ray projection method. The remarkable features of this system -- high speed and continuous measurement -- mainly comes from its image plane constructed by PSD array which is horizontally non-divided and linear, whereas vertically divided in numbers. Each row PSD element is attached to respective analog signal processor, A/D converter and memory element. By the virtue of this configuration of image plane, we can have positional information of slit-like image on image plane stored in respective memory element in real time and continuously. As the result, we can scan the slit-ray at a constant high angular velocity and calculate the deflection angle of it from scanning time of slit-ray, which, in turn, is set on address bus of memory element in our method. Thus, basic datum for 3-D measurement are acquired during only one scanning of the slit-ray at high speed and continuously in the form of addresses of memory elements and datum stored in them.

Trial system verified our method showimg data acquisition time per scene within a few millseconds and enabling us continuous measurement at a rate of hundreds scenes per second.

1. INTRODUCTION

There is widespread interest in obtaining 3-D information i.e. range data by means of machines because of studies and applications of machine perception, pattern recognition, computer vision, robotic vision, computer-aided design and apparel design and so on. 3-D range data would surely serve to solve more easily a wide variety of problems in such fields. So, many techniques have been proposed for obtaining 3-D range information from the image. Of all proposed methods, the binocular stereo method is perhaps the one that has been most actively investigated. But it extracts 3-D range information from a pair of images of gray levels and hence suffers from tremendous computational complexity involved in the post-processing processes such as the matching one of corresponding points between two images. The slit-ray projection method, on the other hand, gives 3-D range information with much simpler computational scheme and so, we think, it may be more prospective at this stage of art. The conventional slit-ray projection systems, however, still have a fundamental problem -- how to acquire useful information in less time. That is, they rely on the scanning type image grabbers such as CCD or ITV cameras and hence, in principle, their data acquisition time becomes much longer than the time required for one frame scanning of the image grabber used. High speed data acquisition would be indispensable to make machines more intelligent and flexible so as to catch up with rapid change in 3-D scene. In this regard, we previously presented a new type of high speed range finder system with newly developed non-scanning type image plane consisted of 2-D array of discrete photo-sensors([1],[2]). Although the trial instrument of that system verified the method to be prospective, to make it ocmpact and convenient to use, the proposed image plane has to be committed to custom VLSI hardware, which requires some further effort to realize. So, this paper newly presents a method which is simpler to realize than the previous one and enables us not only high speed but also continuous 3-D range measurement([3]).

2. METHOD.

In principle, this method is based on the slit-ray projection method. In the slit-ray projection method, slit-ray is projected on the surface of the target and its optical image i.e. slit-like one is formed on the image plane. Then, the 3-D range information can be easily obtained from the positional informations of both the slit-ray and the resultant slit-like image on the image plane. The conventional slit-ray projection systems, however, have disadvantage described above, which we overcome by newly developing PSD array as the image plane.

The schematic diagram of our system is illustrated in Fig.1. Configuration of the system is similar to that of the previous one. Main difference between them lies on the image planes and the remarkable features of this system -- high speed and continuous measurement -- mainly result from its image plane constructed by Position Sensitive Device (PSD) array which is horizontally non-divided and linear, whereas vertically divided in numbers as shown in Fig.2. Each row PSD element of it is attached to the respective analog signal processer, A/D converter and memory element as shown in Fig.3.

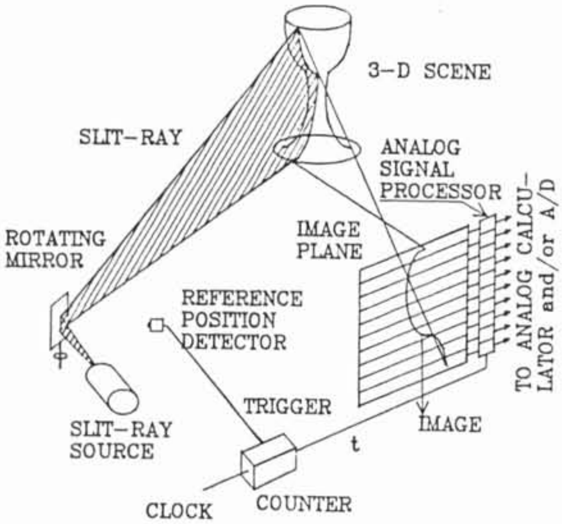


Fig.1 Schematic diagram of the system.

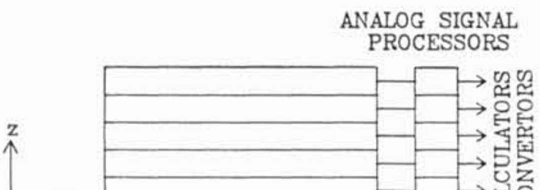


Fig.2 Configuration of image plane.

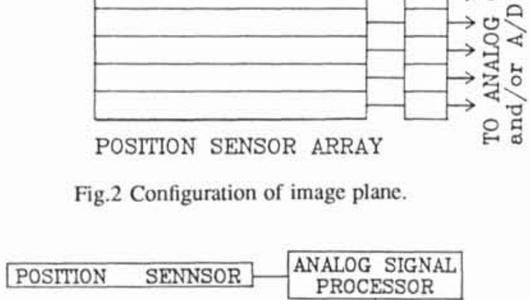


Fig.3 Block diagram of signal processing part.

Now, slit-ray is deflected to scan the field of interest at a constant angular velocity by means of a rotating mirror such as that the polygonal laser scanner on the merket. Then, the resultant slit-like image passes across the image plane with scanning of the slit-ray and each row PSD element outputs analog positional information of the slit-like image on it from time to time through the respective analog signal processor. This analog signal is digitized by means of the A/D converter at an appropriate sampling interval and stored in the respective memory element. Thus, we can acquire the positional information of the slit-like image on the image plane in real time, without waiting for one frame interval as is needed in the conventional methods. As the result, we can scan the slit-ray at a constant high angular velosity and calculate the deflection angle of it from the scanning time of the slit-ray. This scanning time is represented as the elapsed time from the instant the slit-ray passes across the reference position photo-detector (see Fig.1). The light-response output signal from this refference position photo-detector triggers the clock-counter, enabling it to output the above mentioned elapsed time data t. This elapsed time is counted on the basis of the same clock as that of A/D conversion described above and set on the address bus of the memory element (see Fig.3). So, in our method, the address of each memory element gives the deflection angle of the slit-ray and data stored in it gives the position of the slit-like image on the image plane caused by that slit-ray. Thus, basic datum for 3-D measurement are acquired during only one scanning of the slit-ray at high speed. Moreover, if we use large capacity and/or dual-port memories, we may continuously obtain 3-D datum of as many scenes as we want. Since, in this process, no scanning process of the entire image plane as in the prio art is concerned, the system may be able to catch up with remarkably high speed scanning of the slit-ray.

3. TRIAL IMPLEMENTATION

We have implemented this system to verify the method using newly developed PSD array of 30 channels, effective sensor area and response time of which is 27mm x 27mm (0.9mm pitch) and about 5 microseconds, respectivly. Arrays up to 0.1mm pitch are possible to make only at high cost in the stage of trial manufacture. As suggested from the array dimension, we made imageing camera from the optical parts of 35mm camera on the market. The focal length of the lens used is 50mm and its aperture is 1.2. A laser beam is emitted from a laser diode whose wave length is about 810nm and power emitted is about 200mW.

Fig.4 ilustrates a block diagram of the whole trial system. In this trial instrument, the host computer (PC-9800) manages the whole system. The control and signal processing boards are mounted on the expanded bus of the host computer. The control board outputs sampling clock of A/D converter, address to memory element and other control signals.

Analog signals from the PSD array are introduced to input terminals of the signal processing boards, where they are amplified, digitized and stored into the respective memory element. Each board processes signals of 2 channels. 32Kwords memory is allocated to each channel. So, if we allocate 256 words per scene, we can continuously measure 128 scenes. Allocation of the memory as well as

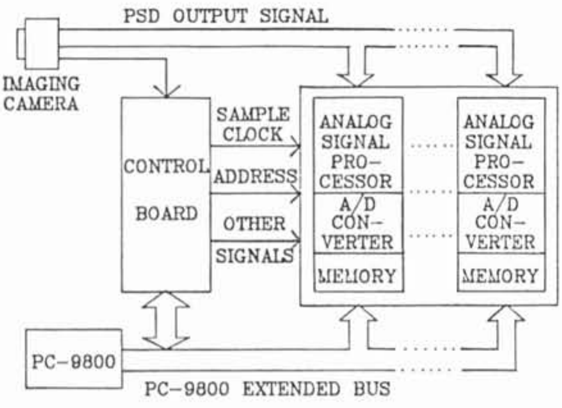
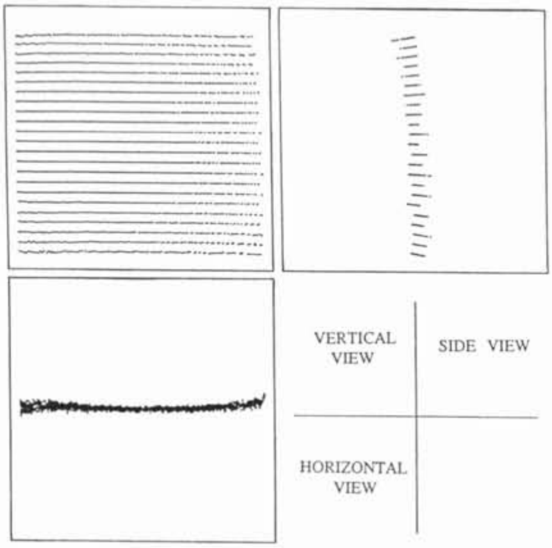
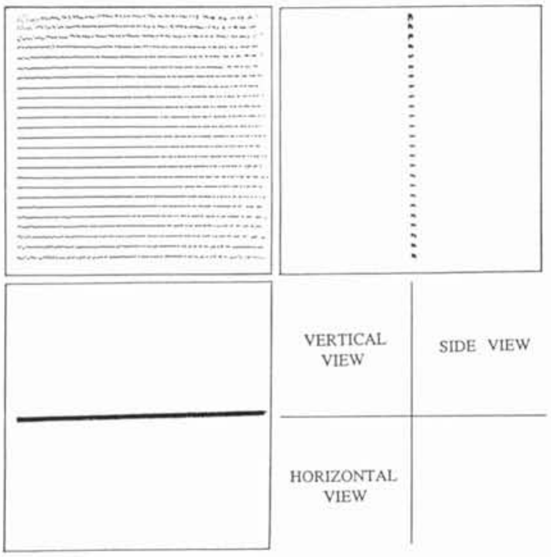


Fig.4 Block diagram of configuration of trial system.



Figs.5 Measured result of vertical plane at the distance of 50cm.



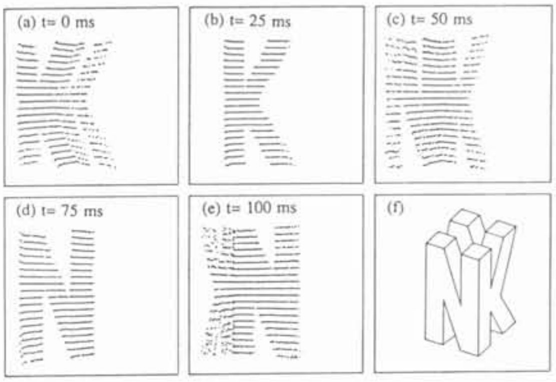
Figs.6 Regression plane obtained from datum shown in Figs.5.

sampling clock interval is programmable by the control board.

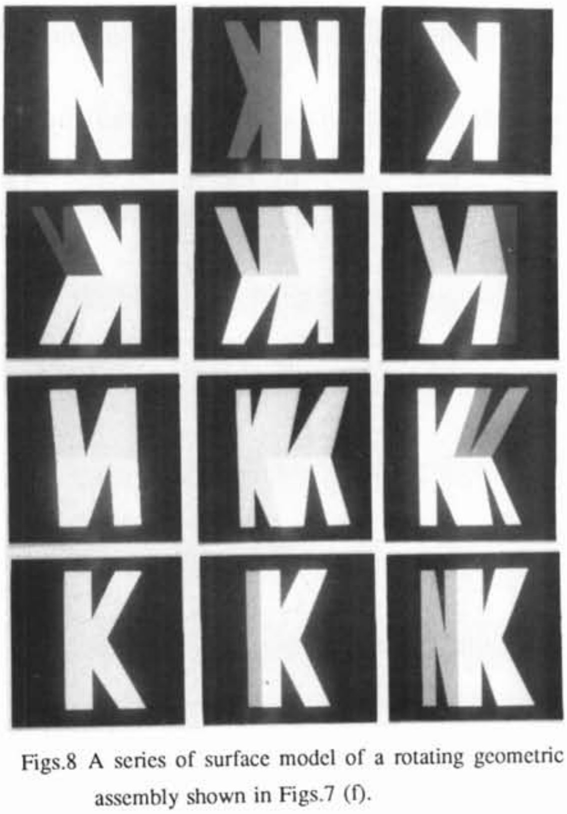
4. MEASURED RESULTS

Fig.5 show the measured result of a vertical plane at the distance of 50cm. The data acquisition time per scene is 10ms. In the figure, upper left, lower left and upper right one are vertical, horizontal and side views, respectively. Although raw datum are rather scattered and further investigation on this point may have to be carried out, the regression plane obtained from these datum is sufficiently accurate as shown in Figs.6.

Next, we tried continuous measurement of moving 3-D objects. Figs.7 (a)-(e) demonstrate the measured result of a



Figs.7 Measured result of a rotating geometric assembly shown in Figs.7 (f).

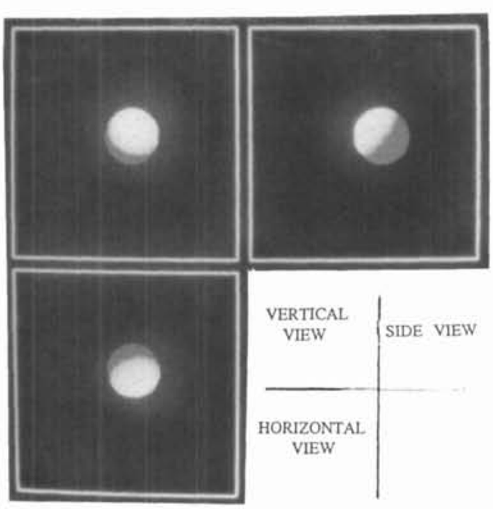


Figs.8 A series of surface model of a rotating geometric assembly shown in Figs.7 (f).

rotating geometric assembly shown in Figs.7 (f). Data acquisition time per scene is also 10ms. For short, all measured results are presented in every five scenes.

Figs.8 represent a series of the reconstructed surface model obtained from datum shown in Figs.7. In this case, we gave the information about data set belonging to the same segment to the computer, then obtained its regression plane, bordered thus obtained regression planes based on measured datum and finally shaded them assuming parallel light beam. Figs.9 show vertical, horizontal and side views of the surface model of a ball reconstructed from raw datum giving information that the surface of the target is spherical. Fig.10 demonstrates a series of vertical views of the surface model of a ball falling freely and then bouncing.

From these resuls, we may be allowed to say that our system enables us to obtain range datum continuously at a rate of hundreds scenes per second. They also suggest that, if we can specify the local shape of the surface of the target from measured results, we easily reconstruct the surface model of the target moving at high speed.



Figs.9 Vertical, horizontal and side views of surface model of a ball.

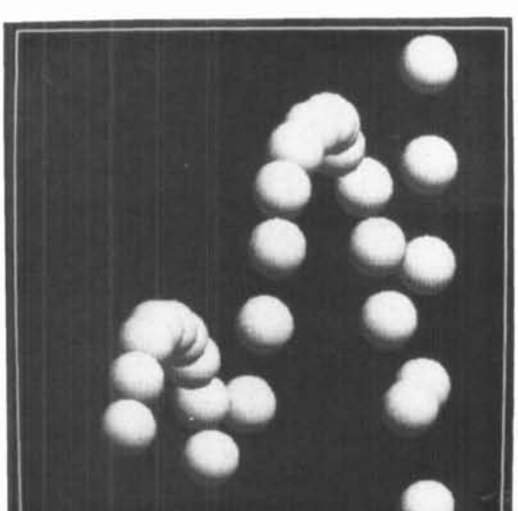


Fig.10 A series of vertical views of surface model of a ball falling freely and then bouncing.

5. CONCLUSION

We have described a new method for high speed and continuous 3-D measurement based on the slit-ray projection one and its trial instrumentation.

The remarkable features of this system -- high speed and continuous measurement -- mainly result from its image plane constructed by Position Senstive Device (PSD) array which is horizontally non-divided and linear, whereas vertically divided in numbers. Each row PSD element is attached to respective analog signal processor, A/D converter and memory element. In our system, analog positional information of the slit-like image on the image plane is amplified, digitized and stored into the respective memory elementin real time. As the result, we can scan the slit-ray at a constant high angular velocity and calculate the deflection angle of it from the scanning time of it, which, in turn, can be related to address of the memory element. Thus, basic datum for 3-D measurement are acquired during only one scanning of the slit-ray at high speed. Moreover, if we use large capacity and/or dural-port memories, we may continuously obtain 3-D range datum of as many scenes as we want.

Trial system was implemented using PSD array of 30 channels and 32K-words memory element per channel. This trial system has verified the method, showing data acquisition time per scene within a few milliseconds and enableing us to measure 3-D range datum continuously at a rate of hundred scenes per second.

ACKNOWLEDGEMENTS

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